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IMAGE CAPTURE CONTROL

This patent application relates to techniques for acquiring images from a solid-state imager when exposure to the scene is 5 controlled by either an asynchronous lighting strobe, or by the asynchronous opening of a shutter. The techniques that we describe do not require an electronic connection between the strobe/shutter and the sensor in order to work, and are hence applicable for use in systems where there is a physical 10 reason, or an electronic reason, why this connection is not feasible.

Solid state image sensors dominate electronic imaging applications such as CCTV, video cameras and camcorders, and 15 scanners, and are the basis of newly developed markets such as PC-cameras for videoconferancing, medical vision, machine vision and Digital Stills Cameras.

One popular form of image sensor is the Charge Coupled Device 20 (CCD), whilst sensors built entirely within standard CMOS processes are also gaining currency. Both have their relative merits when applied to these techniques.

As used herein the expression "asynchronous stimulus" means a 25 stimulus the timing of whose occurrence is not known in advance and which stimulus is associated with the presentation of an image to be captured to the solid state image sensor. As discussed herein various kinds of solid state image sensors known in the art may be used in the present invention, 30 including CCD sensors as well as sensors such as those disclosed in our earlier patent publication WO91/04633, in which, following a resetting of the sensing cells, charge is built up on the sensing cells in response to incident

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radiation impinging thereon and the built up charge subsequently converted into a voltage signal during an integration period, and this cycle repeated upon the next resetting of the sensing cells.

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In some systems it is desirable to separate the operation of the sensor from the exposure mechanism. One such application is Electronic Film, for use in conventional Silver Halide Cameras such as 35mm SLR (Single Lens Reflex). Here the solid

10 state sensor replaces the chemical film within the camera, and as with chemical film the exposure is controlled by the shutter of the camera. In order that such an Electronic Film can work without user modification of the camera to access the shutter control signal, or with older non-electronic cameras,

15 it is necessary for the sensor to auto-detect that it has been exposed. This system must offer a high probability of successful detection, and be scene independent, working under the widest possible range of camera exposures, and additional operating conditions such as flash and fill-in flash.

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Another application is in medical vision and in machine vision, where exposure/illumination occurs through an illumination strobe, and there are physical or electronic reasons why a synchronisation pulse between the light source

25 and the sensor cannot occur. For example it may be necessary to isolate the light source from the detector for reasons of safety, as in an X-ray system.

Fig. 1 shows a conventional general imaging system

30 incorporating a solid state image sensor 1 (incorporating an array of sensing cells) with a shutter 2 (electronic, mechanical or electromechanical), a lighting strobe 3, and a detector 4. The imaging system also includes strobe/shutter

control means 5, and sensor timing and detector control means
6. There is no timing interaction between the strobe/shutter
control means 5, and the sensor timing and detector control
means 6.

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The shutter 2 and/or the lighting strobe 3 provide means of
asynchronous stimulation of the image sensor 1 in order to
capture an image of an object 7 . The classic approach to the
problem would be try to detect the asynchronous event and to
10 then subsequently instigate an exposure and acquisition
sequence for the image sensor. The problem with this approach
is that it puts design pressure on achieving an asynchronous
event detector that is sufficiently fast and reliable that the
interaction between activating the image sensor and the
15 asynchronous stimulus does not corrupt the effective exposure.
Fig. 2 shows a timing diagram of an image acquisition sequence
commonly used with the imaging system of Fig.1, where the
detector triggers the release from reset of the array of the
sensor 1, putting it into integration. The array is then read
20 when the stimulus has gone away. In this example the solid
state image sensor 1 and the detector 4 see the stimulus
simultaneously, as in the case of a lighting strobe 3. As can
be seen the time for the detector to trigger, Td, reduces the
effective amount of the stimulus, Ts, to an amount Te, that is
25 approximately equal to:-

$$Te = Ts-Td$$

If there is a spatial distance between the detector 4 and the
image plane of the solid state sensor 1 with respect to the
30 stimulus, as in the case of a blade shutter 2 in an SLR
camera, then the detector trigger time Td can result in a
gradient of exposure across the array of the sensor 1. Fig.
2b shows an example of what would happen to an array if the

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detector 4 was located to the left hand side of the array, and the shutter 2 was opening from the right hand side of the array. If Tsh1 is the time the shutter takes to cross the array and Tsh2 is the subsequent time for the shutter to pass

5 from the array to the detector, then as the diagram shows the two sides of the array see different effective stimuli, Te1 and Te2, as defined by:-

Te1 = Ts-Td-Tsh1-Tsh2

Te2 = Ts-Td-Tsh2

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This problem can be reduced by using detectors on the side of the shutter that opens first, but still if the time to detect Td is greater than the time to reach the array Tsh2, then there will be a gradient of exposures across the array. The

15 effective stimuli will be somewhere between the following values:-

(Ts-Tsh) < Te < (Ts-Td), where Tsh2 > Td

dependant on the position in the array. This is clearly undesirable.

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We describe a more radical approach to the problem that greatly increases the probability of successful detection of the asynchronous event with no degradation of the stimulus.

25 Thus, according to one aspect of the present invention we provide a method of operating a solid state image sensor for the acquisition of an image generated by an asynchronous stimulus, wherein said image sensor is operated in conjunction with at least one detector which, directly or indirectly,

30 detects the said asynchronous stimulus, said image sensor is regularly reset so as to commence integration from a reset state of the sensor each time a predetermined period has elapsed, and an output from said at least one detector prior

to each reset is used to determine whether that reset is
inhibited or not.

According to a further aspect of the invention we provide a
5 method of using a solid state image sensor, comprising an
array of sensing cells, for the acquisition of an image
generated by an asynchronous stimulus, wherein said image
sensor is regularly reset so as to commence integrating from a
reset state of the sensor each time a predetermined period
10 has elapsed, and wherein a portion of the array of the sensor
is read prior to each said reset and the value of this read is
used to determine whether the subsequent reset should be
inhibited or not.

15 According to yet another aspect of the present invention we
provide image capture control apparatus suitable for use with
a solid state image sensor for the acquisition of an image
presented to the sensor in response to an asynchronous
stimulus, said apparatus comprising at least one detector
20 means formed and arranged for detecting, in use of the
apparatus, directly or indirectly, a said asynchronous
stimulus, and reset inhibition control signal output means
formed and arranged for generating a reset inhibition control
signal in response to detection of said asynchronous stimulus
25 and supplying it, directly or indirectly, in use of the
apparatus, to a reset signal generating means operatively
coupled to said solid state image sensor, so as to inhibit the
application of at least one subsequent reset signal to the
sensor.

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The image capture control apparatus may be provided in a
single device. Alternatively, the apparatus may be provided in
the form of separate modules.

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In a further aspect. the present invention provides a camera
having a solid state image sensor, wherein is provided image
capture control apparatus as above-described.

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Preferred embodiments of the invention will now be described
by way of example only and with reference to the accompanying
drawings in which:
Fig.1 is a schematic diagram of an imaging system
10 incorporating a solid state sensor exposed to an asynchronous
stimulus;
Fig.2a is a diagram showing the relative timing of various
operations carried out in a conventional method of operating
the system of Fig.1;
15 Fig.2b is a diagram showing the relative timing of various
operations carried out in a further known prior art method of
operating the system of Fig.1;
Fig.3a is a diagram of the relative timing of various
operations carried out in a method of operating the system of
20 Fig.1 according to the present invention, where an
asynchronous event occurs in a "detect period" Tr;
Fig.3b is a diagram of the relative timing of various
operations carried out in a method of operating the system of
Fig.1 according to the present invention, where the
25 asynchronous event straddles two detect periods Tr;
Fig.3c is a diagram of the relative timing of various
operations carried out in a method of operating the system of
Fig.1 according to the present invention, where the
asynchronous event occurs close to the end of the detect
30 period Tr;
Fig.4 is a diagram of the relative timing of various
operations carried out in another method of operating the
system of Fig.1 according to the present invention, in which a

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portion of the sensor array is used to detect the asynchronous
stimulus; and

Fig.5 is a block diagram of one embodiment of image capture
control apparatus for carrying out the method of the
5 invention.

The method of the invention can be briefly described in the
following manner, with reference to the imaging system of
Fig.1:-

10 a)   The image sensor is regularly reset, at a repetition rate
        of 1/Tr. The period Tr between each reset pulse R is
        hereinafter referred to as the detect period Tr. In this
        period Tr between the reset pulses R the image sensor 1 is
        integrating any incident light.

15 b)   If during a given detect period Tr the detector 4 has
        fired, indicating that there has been some asynchronous
        stimulus, which is of duration Ts, then the next reset
        pulse R' is inhibited, and the sensor enters its
        "continued integration period", Tc.

20 c)   In the continued integration period, Tc, the integration
        of the array is continued to beyond the extent of the
        longest asynchronous stimulation, Ts(max). This may
        either be a fixed time or a time based on a trigger by a
        detector that the stimulus has gone away. The sensor now
25   enters the readout period.

   d)   In the array readout period, Ta, the array is readout, and
        can then go back to the detect period Tr to await the next
        asynchronous event (i.e. stimulus).

30 We have called this approach the 'inhibited reset' approach.

Fig 3a shows the basic timing for an asynchronous event S that
occurs totally inside the detect period Tr, and Fig 3b an

event S that would straddle a reset pulse R (hereinafter
referred to as a "reset" R), but for the 'inhibited reset'
(i.e. the event S straddles the inhibited reset R'). The time
for the detector to fire is Td, and the probability of
5 acquiring the asynchronous event without any corruption is :-

Probability of success = (Tr-Td)/Tr and normally Tr >> Td

Note in both cases the effective exposure, Te3, seen by all of
10 the array and the detector is the full time of the stimuli,

Te3 = Ts

Fig 3c shows the case where the stimulus occurs < Td away from
15 where the reset R would occur. In this case the reset R would
NOT be inhibited in time, but it is important to note that
this is no worse than the classic approach described earlier
with reference to Fig.2c.
In this case the effective exposure, Te4 is :-
20
Te4 = Ts - Td

Fig.5 illustrates schematically one embodiment of image
capture control apparatus for implementing the above-described
25 method of the invention. The apparatus 10 comprises the
detector 4, a reset signal generating unit 11 for generating
the reset signals R, and reset inhibition control signal
output means 12 for generating a reset inhibition control
signal for supplying to the reset signal generating unit 11.
30 When the detector 4 detects an asynchronous stimulus it
outputs a detection signal D (see Fig.3) to the reset
inhibition control signal output means 12 which generates a
reset inhibition control signal Cr which is supplied to the

reset signal generating unit 11 so as to inhibit the
application of the subsequent reset pulse R' to the sensor
array. It will be appreciated that the reset inhibition
control signal output means 12, if desired, may be
5 incorporated in the detector 4 (e.g. in a single device), or
may be incorporated in the reset signal generating unit 11, or
may be provided as a separate module. Similarly, the reset
signal generating unit 11 may be incorporated in the sensor 1.
Equally, the apparatus 10 may together be incorporated in the
10 image sensor 1, if desired, or may be provided as one or more
separate modules for use therewith.

The detector 4 in both the classic approach and the 'inhibited
reset' approach need not be a direct detector, i.e. another
15 optical sensor that is also looking for the same type of
optical stimuli, although this is by far the most popular
approach. An example of an indirect detector which could be
used is a vibration transducer, or a sound transducer, for
detecting the movement of a physical shutter.
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In the case of the optical detector 4, it is often co-located
with the image sensor 1, but it is not possible to put it in
the same focal plane as the image sensor. This can give
problems in a lensed system as the detector may not be focused
25 on a part of the scene with sufficient luminance to trigger
it.

However, with our 'Inhibited reset approach' it is possible to
use a sub-sampled portion of the sensor array, in such a way
30 that the sensor array itself can act as the detector of the
asynchronous stimulus. This is because the array is already
integrating during its detect period, therefore by reading it
before the decision to inhibit reset or not, we have a sample

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of the light that has been integrated by the array. By
comparing these values with the values obtained when there has
been no stimulus, we have a measure of the change. If this
change is greater than a user defined threshold, then we say
5 that an asynchronous stimulus has occurred. The choice of
this threshold, relative to the lowest energy stimulus it is
desired to detect, determines the effective time to detect,
Td, in the following way. With reference to Fig.4, if Ts is
the longest stimuli to cause saturation of the image sensor,
10 Tsa is the time to read the sub-array, and Pt is the
percentage of saturation that is required to trigger a
threshold of detection, then the effective Td is

$$Td = (Ts * Pt) + Tsa$$
15

The major advantage of this approach is that the array itself
is acting as the detector and is therefore in the focal plane
of the focused image. Spatially distributing the sub-sample,
greatly increases the probability that some of the pixels of
20 the sub-sample are in areas with sufficient luminance.

It is of course possible to use our described 'Inhibited reset
approach' with a plurality of detectors and sub-sampled
arrays, to determine if an asynchronous event has occurred.
25

Various other modifications and variations of the above-
described embodiments are also possible without departing from
the scope of the invention. For example, in relation to the
continued integration period, Tc, it will be appreciated that
30 this could be an extended period corresponding in effect to
the inhibition of more than one reset pulse i.e. a series of
successive reset pulses.